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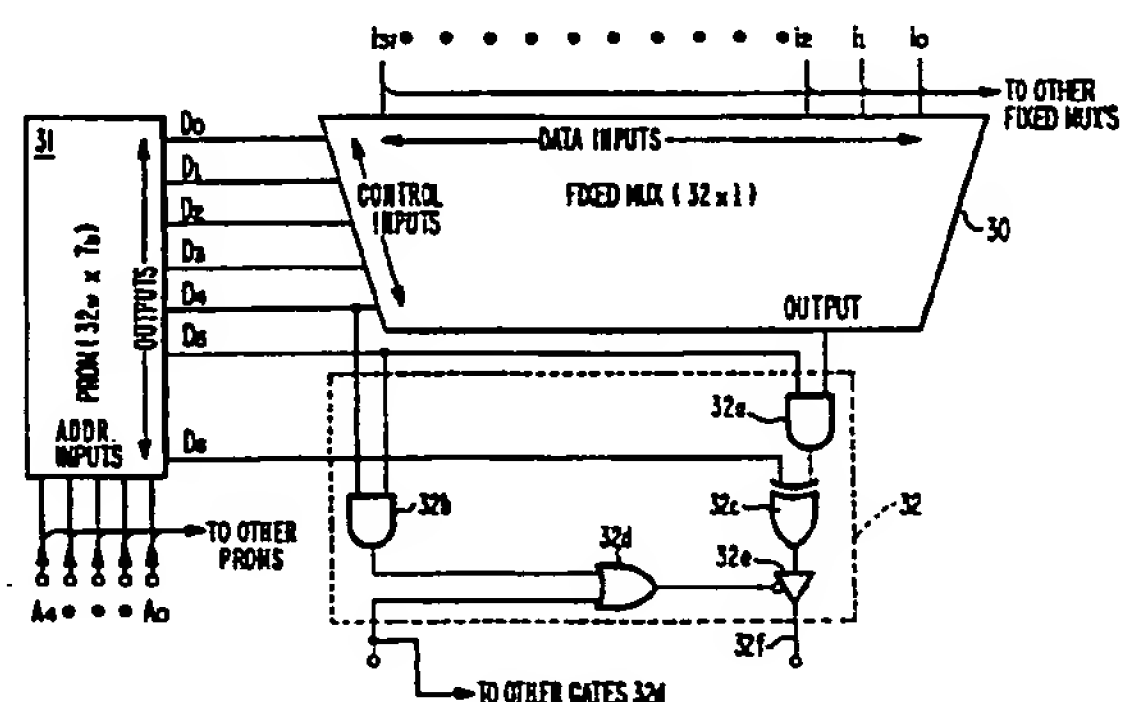
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⑤④ Programmable multiplexer.

⑤⑦ Disclosed is a programmable multiplexer integrated on a semiconductor chip comprised of a plurality of fixed multiplexer circuits (30), each of which includes a plurality of data inputs, a plurality of control inputs, and an output for passing a signal from any one of the data inputs to the output in a fixed predetermined fashion in response to encoded signals on the control inputs; and associated with each of the fixed multiplexer circuits (30) is a programmable memory (31) for generating the encoded control signals by performing respective programmable transformations of one common address that is sent to all of the memories (31).



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TITLE

PROGRAMMABLE MULTIPLEXER

BACKGROUND OF THE INVENTION

5 This invention relates to the architecture of
a particular type of digital logic circuit called a
programmable multiplexer.

10 In general, practically all digital logic
circuits are packaged on semiconductor chips in accordance
with the particular function that they perform. See, for
example, The TTL Data Book for Design Engineers, 2nd
Edition, Texas Instruments, Section 1 page 9 wherein
several logic circuit chips are listed according to their
function, and in particular note the "data selector-multiplexer"
chips since they relate directly to the subject of this
15 invention.

Each data selector-multiplexer chip there listed
contains one or more fixed multiplexer circuit which is herein
defined as a circuit having a plurality of data inputs, a
plurality of control inputs, and an output. In operation,
20 control signals are applied to the control inputs, and in

response the fixed multiplexer circuit selectively passes a signal from one of the data inputs to the output. In other words, the data inputs are multiplexed to the output in response to the control signals in a fixed predetermined fashion.

Typically, several fixed multiplexer circuits are fabricated on a single chip. See, for example, the Texas Instruments chips 54LS253 and 74LS253 in Section 7, page 369 of the above-cited reference. These chips contain two such circuits, each of which has four data inputs and one output; and the data inputs on both of those circuits are selected by control signals that are common to both circuits.

One significant limitation, however, to these 54LS253 and 74LS253 chips and other similar prior art chips containing several fixed multiplexer circuits is that they are too inflexible. More specifically, the data inputs which the several fixed multiplexer circuits select in response to the control signals cannot be picked in any desired combination. Instead, the data inputs which pass to the outputs in response to the control signals are fixed. Typically, in response to control signals encoded as a "binary one", all of the fixed multiplexer circuits select their "first" data input; in response to control signals encoded as a "binary two", all of the fixed multiplexer circuits select their "second" data input; etc.

To overcome this problem, a "programmable multiplexer" chip has been recently introduced into the market by a company called Monolithic Memories. This programmable multiplexer chip has a part number 29693, and its block diagram is illustrated in Figure 1.

As there illustrated, this programmable multiplexer is comprised of four fixed multiplexer circuits 11-14 and a

corresponding number of fusible link arrays 15-18.

In operation, input signals $i_0 - i_9$ are received on the chip by buffers 20; and their outputs are sent to the fusible link arrays. Outputs from the fusible link arrays 15-18 are then sent to the fixed multiplexer circuits 11-14 respectively.

Circuits 11-14 pass their inputs to their output in a fixed predetermined fashion in response to a common set of control signals $S_0 - S_2$. But this 29693 chip is much more flexible than the aforementioned Texas Instruments 54LS253 and 74LS253 chips because the fuse arrays enable the input signals $i_0 - i_8$ to be passed to the fixed multiplexer circuits 11-14 in any desired combination.

Suppose, for example, that it is desired to pass inputs i_7, i_2, i_8 , and i_0 through the fixed multiplexer circuits 11, 12, 13 and 14 respectively in response to S_0, S_1, S_2 signals of 001. Assuming that a 001 code selects the first input on each of the fixed multiplexer circuits 11, 12, 13, and 14, then the above result is achieved by merely blowing the appropriate fuses in arrays 15, 16, 17, and 18 such that input i_7 is sent to the first input of fixed multiplexer circuit 11, input i_2 is sent to fixed multiplexer circuit 12, etc.

However, despite the above-described desirable feature of the Figure 1 programmable multiplexer chip, that chip also has several very significant drawbacks. And these drawbacks, along with the features and advantages of the present invention, are described in detail in the following Detailed Description in conjunction with Figures 2-5.

Accordingly, a primary object of the present invention is to provide an improved programmable multiplexer chip as described in conjunction with Figures 2-5.

BRIEF SUMMARY OF THE INVENTION

This object is achieved in the present invention by providing a plurality of fixed multiplexer circuits and a corresponding number of programmable memories on
5 a semiconductor chip. Each of the fixed multiplexer circuits includes a plurality of data inputs, a plurality of control inputs, and an output for passing a signal from any one of the data inputs to the output in a fixed predetermined fashion in response to encoded signals on
10 the control inputs; and each of the memories includes an address input and parallel outputs for generating signals thereon as a programmable transformation of the memory address.

All of the fixed multiplexer circuits have their
15 data inputs intercoupled together such that they receive the same data input signals; all of the memories have their address inputs intercoupled together such that they receive the same address; and the memories also have their outputs respectively coupled to the control
20 inputs of the plurality of fixed multiplexer circuits. Thus, the encoded control signals for the plurality of fixed multiplexers are formed by respective programmable transformations of a memory address, which in turn enables any combination of data inputs to be passed to the fixed
25 multiplexer circuit outputs.

BRIEF DESCRIPTION OF THE DRAWINGS

Various features and advantages of the invention will best be understood by reference to the following
30 Detailed Description and accompanying drawings wherein:

Figure 1 is a logic diagram, for comparison purposes, of a programmable multiplexer chip constructed according to the prior art;

Figure 2 is a logic diagram of a programmable multiplexer chip constructed according to one preferred embodiment of the invention;

5 Figure 3 is a chart which compares the number of fuses that are required to implement the programmable multiplexers of Figures 1 and 2;

Figure 4 is a logic diagram illustrating the expandability of the data inputs of the programmable multiplexer chip of Figure 2; and

10 Figure 5 is a chart illustrating the operation of the Figure 4 logic diagram.

DETAILED DESCRIPTION OF THE INVENTION

15 Referring now to Figure 2, one preferred embodiment of a programmable multiplexer chip constructed according to the invention will be described. This embodiment includes a plurality of identical fixed multiplexers, one of which is shown in Figure 2 as indicated by reference numeral 30. All of the fixed multiplexer circuits have 32
20 data inputs, five control inputs, and one output; and they all have their data inputs coupled together such that they receive the same data input signals $i_0 - i_{31}$.

Each of the fixed multiplexer circuits 30 has a separate programmable read-only memory 31 associated with it.
25 Memory 31 contains thirty-two words, each of which is seven bits in length. These words are read from the memory via signals $A_0 - A_4$ that are applied to the memory's address inputs. All of the memories have their address inputs coupled together to receive the same address
30 signals $A_0 - A_4$ in parallel.

Also associated with each of the fixed multiplexer circuits 30 and its memory 31 is a separate logic circuit,

one of which is indicated by reference numeral 32. Each of these logic circuits includes a pair of AND gates 32a and 32b, an exclusive OR gate 32c, an OR gate 32d, and an output driver 32e. These components are interconnected to their respective fixed multiplexer circuit and memory as illustrated in Figure 2.

In operation, address $A_0 - A_4$ is sent to all of the memories 30 in parallel. Each of those memories responds by generating output signals $D_0 - D_6$ as determined by the addressed word. In other words, signals $D_0 - D_6$ are a programmable transformation of the address. Signals $D_0 - D_4$ are then sent to the fixed multiplexer circuit 30 to control its output, whereas signals $D_4 - D_6$ are sent to logic circuit 32 to control that circuit's output.

Suppose, as a specific example, that in response to a particular address, fixed multiplexer circuit 30 is to pass data input i_2 to its output. This is achieved by programming the addressed word in memory 31 such that output signals $D_0 - D_4$ select input i_2 . For that same memory address, however, the words in the other memories can be encoded differently; and thus any set of data inputs can be sent through the fixed multiplexer circuits in response to a particular memory address.

One important feature of the above-described programmable multiplexer chip is that it not only provides the programmable multiplexing function, but it does this with substantially less circuitry than the prior art required. In particular, the number of fuses which the Figure 2 chip requires is substantially reduced.

This is evident by an inspection of Figure 3 which compares the number of fuses that are required to

implement a programmable multiplexer chip having
thirty-two data inputs and sixteen outputs via the
circuitry of Figures 1 and 2. Calculations for that
chip according to the prior art of Figure 1 are made in
5 row 1; whereas calculations for that chip according to
Figure 2 are made in row 2.

As indicated in the leftmost column of Figure 3,
both embodiments have thirty-two data inputs; and as
indicated in the next adjacent column, it is assumed for
10 the purposes of this calculation that there are thirty-two
multiplexing functions per output. In other words, it is
assumed for the purposes of this comparison that there
are five control signals going into each fixed
multiplexer circuit. Those control signals have thirty-two
15 combinations which direct each fixed multiplexer circuit
to make thirty-two different selections.

Therefore, as shown in the next column, each fuse
array in the Figure 1 embodiment will contain 32 X 32
fuses. But by comparison, each programmable memory such
20 as memory 31 in the Figure 2 embodiment will only contain
32 X 5 fuses. That will provide thirty-two words of five
bits each; and each of those five-bit words will pass
one data input through the fixed multiplexer circuit.

Again, for the purposes of this comparison, this
25 chip is assumed to have sixteen outputs. Therefore, the
total number of fuses per chip in the Figure 1 embodiment
will be 32 X 32 X 16 or 16,384; whereas the total number of
fuses in the Figure 2 embodiment will only be 32 X 5 X 16
or 2,560. Consequently, with this invention there is a
30 savings of 14,124 fuses!

Also, another important feature of this invention
is that the logic circuit 32 in combination with memory 31

provides several additional functions which simply are not obtainable in the prior art. One of these functions is that the inverse of data inputs $i_0 - i_{31}$ can be selectively transferred to the logic circuit's output 32f. Another of these functions is that a digital "1" or a digital "0" can be selectively sent to output 32f regardless of the state of the multiplexer's data inputs. And still another of these functions is that the number of data inputs that are multiplexed to a particular chip's output can be expanded.

Consider now the details of how these functions are obtained. Firstly, to pass the inverse of a particular data input to output 32f, memory 31 is programmed to generate signals D_5 and D_6 as a digital "11". A "1" for signal D_5 causes the output of fixed multiplexer 30 to pass through AND gate 32a; and a "1" for signal D_6 causes EXCLUSIVE OR gate 32c to invert the output of AND gate 32a. That inverted signal is then sent to output 32f.

Note, by comparison, that a selected data input is sent directly to output 32f in response to signals D_5 and D_6 from memory 31 being programmed as a "10". A "1" for signal D_5 causes the output of multiplexer 30 to pass through AND gate 32a; and a "0" value for signal D_6 causes the output of AND gate 32a to pass directly through EXCLUSIVE OR gate 32c and to output 32f.

Next, to generate a "0" on output 32f regardless of the state of the data inputs $i_0 - i_{31}$, signals D_5 and D_6 from memory 31 are programmed as a "00". Signal D_5 being a "0" forces the output of AND gate 32a to a "0"; and signal D_6 being a "0" causes the "0" output of AND gate 32a to pass directly through EXCLUSIVE OR gate 32c.

Next, to generate a "1" on output 32f, signals D_5 and D_6 from memory 31 are programmed as a "01". Gate 32a generates a "0" on its output in response to signal D_5 being a "0"; and EXCLUSIVE OR gate 32c
5 generates a "1" on its output in response to one of its inputs being "1".

To generate signals D_5 and D_6 in addition to signals $D_0 - D_4$ requires two additional fuses per word in memory 31. Thus, as indicated in row 3 of Figure 3, the
10 total number of fuses per output is 32×7 ; and the total number of fuses per chip is 3,584. But this is still 12,800 fuses less than the number of fuses required by the prior art circuit of Figure 1.

Next, to understand how the number of data inputs
15 that are multiplexed to a particular chip's output can be increased, reference should be made to Figure 4. In that figure, two identical programmable multiplexer chips which are constructed according to the invention are labeled as "chip 1" and "chip 2". Each of these chips
20 contains all of the Figure 2 circuitry repeated 16 times. Boxes 41, 42, 43 and 44 represent respective copies of that circuitry.

Data input signals $i_0 - i_{31}$ are sent to circuits 41 and 42 on chip 1 where they are then multiplexed to
25 respective outputs O_1 and O_2 , each of which corresponds to an output 32f. Similarly, data input signals $i_{32} - i_{63}$ are sent to circuits 43 and 44 on chip 2 where they are then multiplexed to respective outputs O_1 and O_2 . Outputs O_1 and O_2 from chips 1 and 2 are then interconnected by
30 conductors 51 and 52.

With this circuit, any of the data input signals $i_0 - i_{63}$ can be gated in any desired combination onto

conductors 51 and 52. Suppose, for example, that it is desired to gate signals i_0 and i_{63} onto conductors 51 and 52 respectively. To accomplish this, memory address $A_0 - A_4$ is programmably transformed as indicated by row 1 in the chart of Figure 5.

That row indicates that the memories 31 in circuits 42 and 43 are programmed to generate output signals D_4 and D_5 as a "10". This causes AND gate 32b to generate a "1" on its output; that "1" passes through OR gate 32d to driver 32f; and driver 32e must receive a "0" from gate 32d to be enabled. Consequently, driver 32d is disabled, which connects a tri-state high impedance to output 32f.

Since logic circuits 42 and 43 generate no signals on conductors 51 and 52, the signals on those conductors are determined solely by circuits 41 and 44. Consequently, signal i_0 is passed to conductor 51 by programming signals $D_0 - D_4$ in circuit 41 to select input i_0 and by programming signals D_5 and D_6 to a "10". Similarly, signal i_{63} is passed to conductor 52 by generating signals $D_1 - D_4$ to select input i_{63} and by generating signals D_5 and D_6 to a "10".

This expandability of the data inputs simply is not possible to obtain with the prior art chip of Figure 1. There, all of the chip's outputs $O_1 - O_4$ are either enabled or disabled together in response to one common signal \bar{E} . Thus, when outputs $O_1 - O_4$ from two of those chips are wire-ORed together, it is impossible to pass input signals from one of those chips to output O_1 and at the same time pass input signals from the other chip to output O_2 .

Other examples of how any combination of the data input signals $i_0 - i_{63}$ as well as their inverse and the internally generated "0" and "1" signals can be passed to conductors 51 and 52, are indicated in the remaining rows of Figure 5. Row 2, for example, indicates how inputs i_{63} and i_0 are respectively passed to conductors 51 and 52; row 3 indicates how the inverse of i_0 and a "0" are respectively generated on conductors 51 and 52; and row 4 indicates how a "1" and the inverse of signal i_0 are respectively generated on conductors 51 and 52. In each case, outputs O_1 and O_2 from chips 1 and 2 are selectively disabled as indicated by the encircled "100" values of signals D_4, D_5, D_6 , where "0" means don't care.

Various preferred embodiments of the invention, as well as the features and advantages thereof, have now been described in detail. In addition, however, many changes and modifications can be made to these details without departing from the nature and the spirit of the invention. For example, it is to be understood that programmable memory 31 may be constructed with a wide variety of technologies. For example, the fuses within memory 31 may be comprised of polysilicon and the memory address decoders and output drivers may be comprised of bipolar transistors such as those in the Intel 3628A 1K X 8 bipolar programmable memory chip.

As another alternative, memory 31 may be constructed as an ultraviolet erasable memory in which each fuse is replaced by a floating gate field-effect transistor. That is, this embodiment would include no fuses at all; but instead, the fuses previously discussed in conjunction with rows 2 and 3 of Figure 3 would be replaced by an equal number of floating gate field-effect transistors. In

General, a bit in this type of memory is programmed to a "0" by selectively storing charge on the floating gate of the particular field-effect transistor corresponding to that bit; and the memory is programmed to all "1s" by radiating all of the floating gate field-effect transistors with ultraviolet light. This type of memory construction is utilized, for example, in the Intel 2716 programmable memory chip.

Accordingly, it is to be understood that the invention is not limited to said details but is defined by the appended claims.

WHAT IS CLAIMED IS:

1. An improved programmable multiplexer circuit integrated on a semiconductor chip comprised of:
 - a plurality of fixed multiplexer means and a corresponding plurality of programmable memory means;
 - 5 each of said fixed multiplexer means including a plurality of data inputs, a plurality of control inputs, and an output for passing a signal from any one of said data inputs to said output in a fixed predetermined fashion in response to encoded signals on said control inputs;
 - 10 each of said memory means including an address input and parallel outputs for generating signals thereon as a programmable transformation of an address signal on said address inputs;
 - all of said fixed multiplexer means having their
 - 15 data inputs intercoupled together such that they all receive the same data input signals;
 - all of said memory means having their address inputs coupled together such that they all receive the same address signals; and
 - 20 said plurality of memory means having their outputs respectively coupled to said control inputs of said plurality of fixed multiplexer means to provide said encoded control signals as respective programmable transformations of said same memory address.

2. A programmable multiplexer according to Claim 1 and further including a plurality of logic circuit means corresponding in number and respectively coupled to said plurality of memory means for receiving said control
5 signals therefrom; each of said logic circuit means having an output and being responsive to its respectively received control signals for selectively coupling a respective one of said multiplexer output signals or a tri-state impedance to its output.
3. A programmable multiplexer according to Claim 2 wherein each of said logic circuit means further includes a means responsive to its respectively received control
5 signals for selectively generating a logic zero or a logic one on its output regardless of the signal passed to said multiplexer output.
4. A programmable multiplexer according to Claim 2 wherein each of said logic circuit means further includes a means responsive to its respectively received control
5 signals for selectively coupling the inverse of a respective multiplexer output signal to its output.
5. A programmable multiplexer according to Claim 1 wherein each of said memory means includes an array of fuse means for selectively programming said transformation of said address.

6. A programmable multiplexer according to Claim 1 wherein each of said memory means includes an array of floating gate field-effect transistor means for selectively programming said transformation of said address.

7. A programmable multiplexer according to Claim 1 wherein each of said memory means and fixed multiplexer means is comprised of a plurality of bipolar transistors.

8. A programmable multiplexer according to Claim 1 wherein each of said memory means and fixed multiplexer means is comprised of a plurality of field-effect transistors.

9. An improved programmable multiplexer circuit integrated on a semiconductor chip comprised of:
- a plurality of fixed multiplexer means; each of said fixed multiplexer means including a plurality of data inputs, a plurality of control inputs, and an output for passing a signal from any one of said data inputs to said output in a fixed predetermined fashion in response to encoded signals on said control inputs; wherein
- associated with each of said fixed multiplexer means is a programmable memory means for generating said encoded control signals by performing respective programmable transformations of an address that is the same for all of said memory means.

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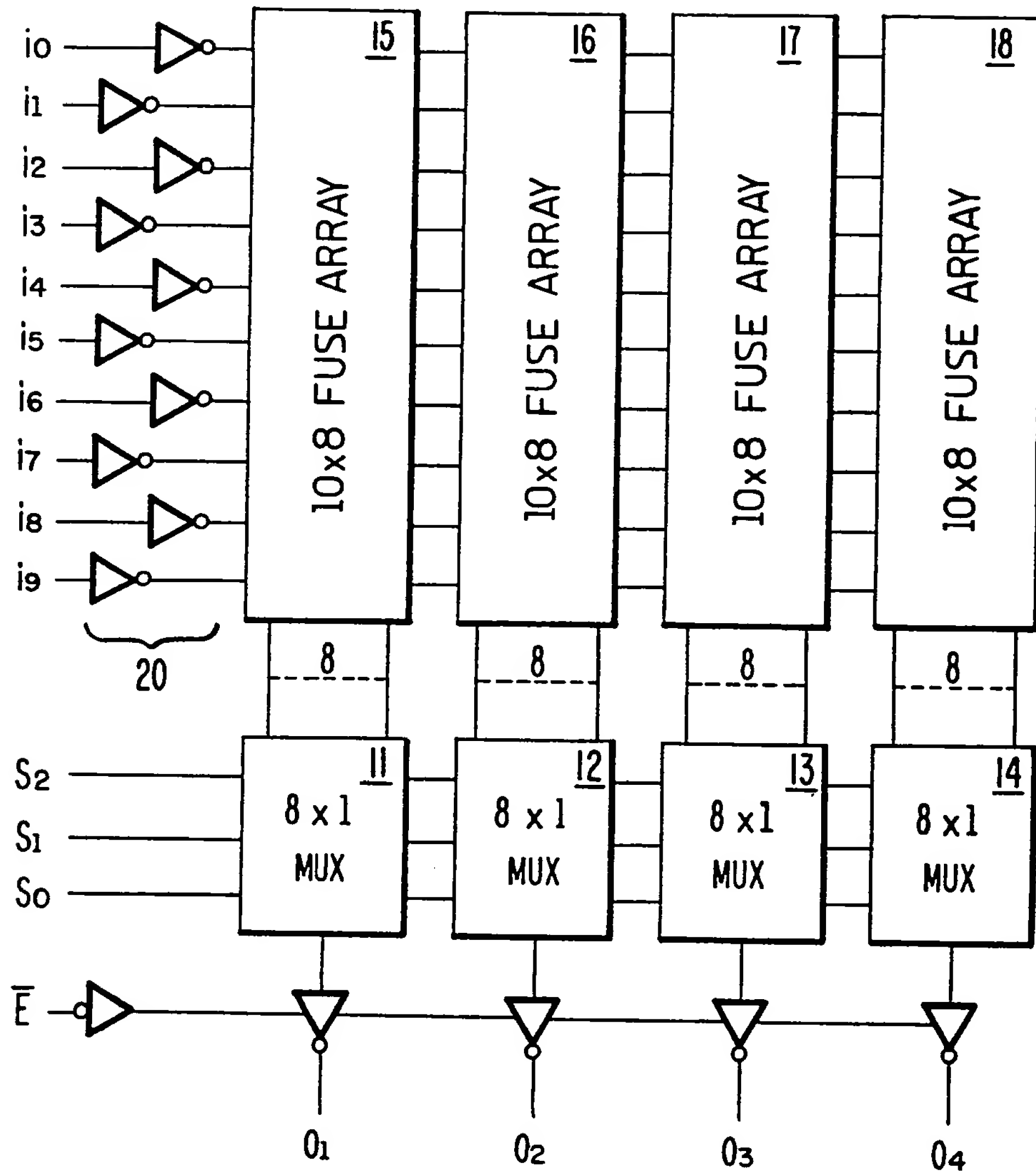
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10. An improved programmable multiplexer circuit
according to Claim 9 wherein associated with each of said
memory means and corresponding multiplexer means is a
logic circuit means having an output for selectively
5 coupling thereto a tri-state high impedance or the inverse
of the multiplexer's output in response to encoded control
signals from the memory means.



FIG. 1. Prior Art.

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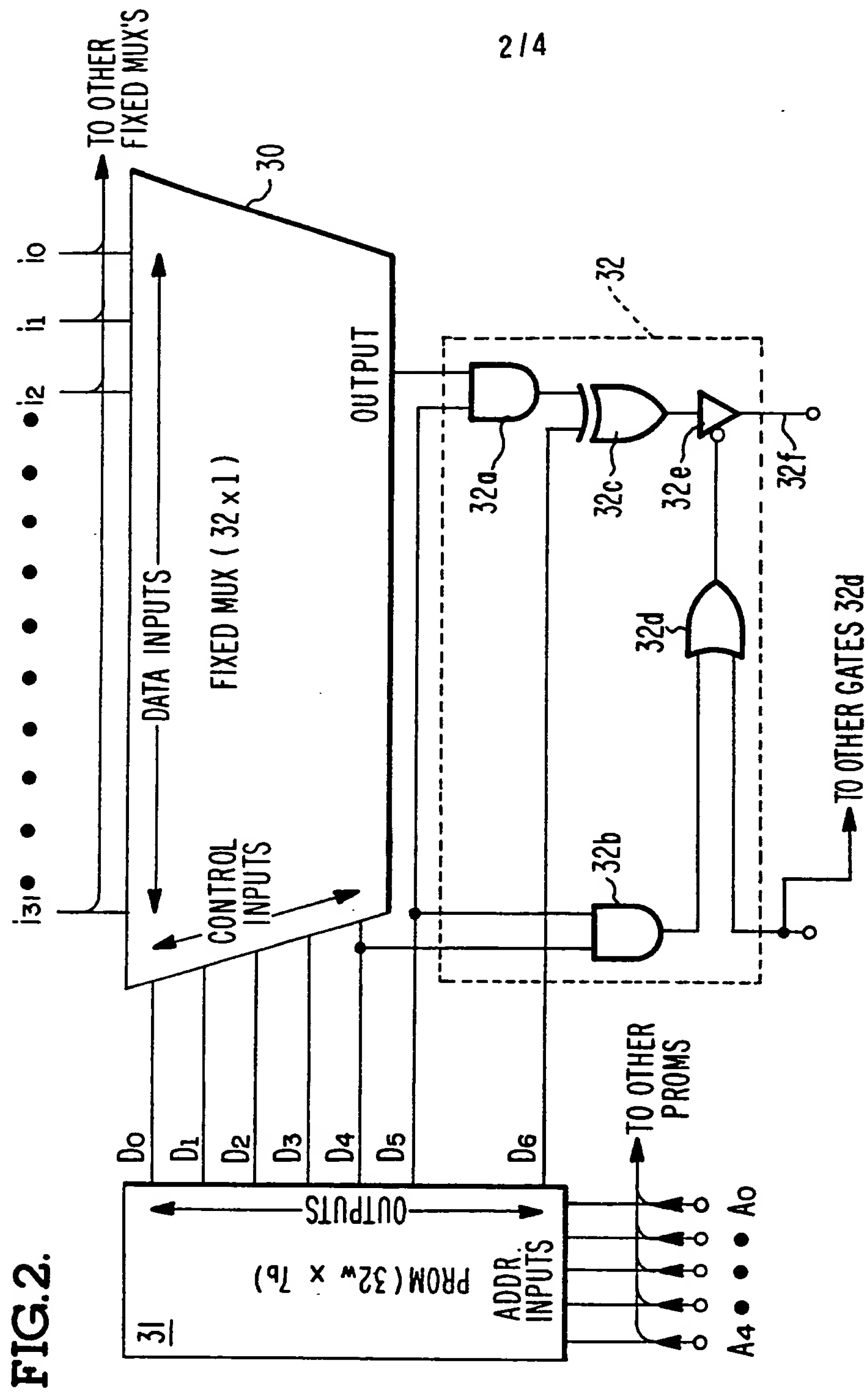


FIG.2.

FIG.3.

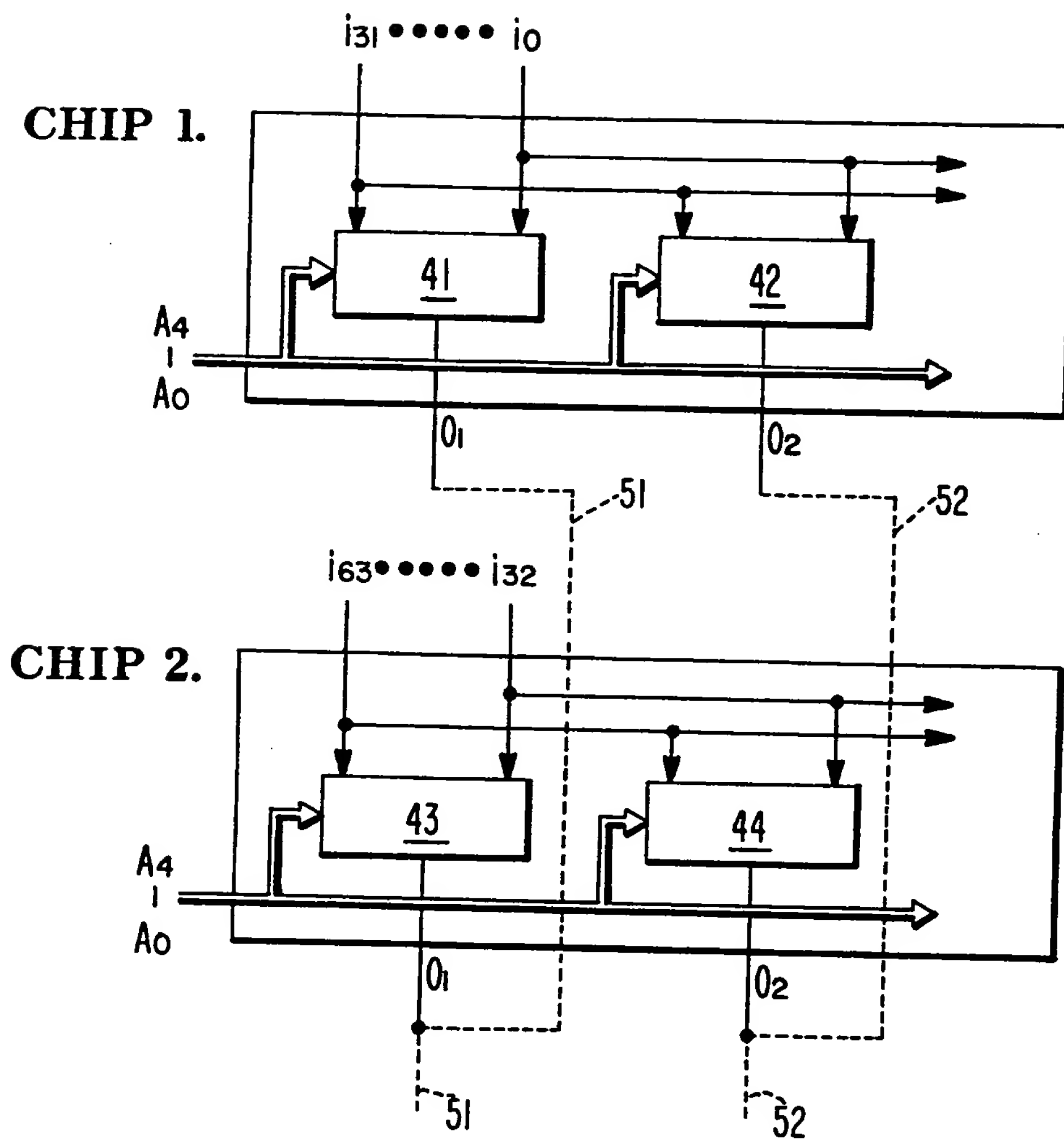
	DATA INPUTS PER CHIP	SELECTIONS PER OUTPUT	FUSES PER OUTPUT	OUTPUTS PER CHIP	TOTAL FUSES PER CHIP	SAVINGS
Prior Art						
ROW ONE → (FIG. 1.)	32	32	32x32	16	16,384	
EMBOD. OF ROW TWO → (FIG. 2.)	32	32	32x5	16	2,560	14,124
EMBOD. OF ROW THREE → (FIG. 2.)	32	32	32x7	16	3,584	12,800

FIG.5.

	51	52	41 D4 D5 D6	42 D4 D5 D6	43 D4 D5 D6	44 D4 D5 D6
ROW ONE →	i0	i63	-10	100	100	-10
ROW TWO →	i63	i0	100	-10	-10	100
ROW THREE →	$\bar{i}0$	0	-11	000	100	100
ROW FOUR →	1	$\bar{i}0$	-001	-11	100	100

FIG.4.

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European Patent
Office

EUROPEAN SEARCH REPORT

0081917

Application number

EP 82 30 6098

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
A	--- ELECTRONIC ENGINEERING, vol. 52, no. 633, January 1980, T.L. LARSON et al. "Field programmable logic devices", pages 37, 39, 41, 43, 45, 57, 49-50, 52, 54 * Figure 8 ; section : PMUX *	1,5,9	H 03 K 17/62 H 03 K 17/693 H 03 K 19/173 G 06 F 9/22
A	--- ELECTRONICS, vol. 51, no. 10, May 1978, D. WYLAND "Managing the flow of data is easy with programmable multiplexer", pages 132-135 * Figure 1, pages 132, 133 *	1,5,9	
A	--- US-A-4 121 055 (M.J. DOHERTY) -----		
The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (Int. Cl. 3)
			G 06 F 9/22 H 03 K 17/62 H 03 K 17/693 H 03 K 19/02 H 03 K 19/173 H 04 J 3/00 H 04 J 3/02 H 04 J 3/04
Place of search BERLIN		Date of completion of the search 27-01-1983	Examiner ARENDT M
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	